Republic of Iraq

Ministry of Higher Education

and Scientific Research

Al-Mustaqbal University

Chemical Engineering and Petroleum Industries Department

Subject: Combustion engineering

3nd Class

FLAME SPEED CORRELATIONS FOR SELECTED FUELS

Metghalchi and Keek experimentally determined laminar flame for various fuel-air mixtures over a range of temperatures and pressures typical of conditions associated with reciprocating internal combustion engines and gas-turbine combustors.

$$S_L = S_{L,\mathrm{ref}}\left(\frac{T_u}{T_{u,\mathrm{ref}}}\right)^{\gamma}\left(\frac{P}{P_{\mathrm{ref}}}\right)^{\beta}(1-2.1Y_{\mathrm{dil}}),$$

For T_u> 350 K . The subscript ref refers to reference conditions defined by $T_{u.ref} = 289K$ and P =1 atm .

$$S_{L,ref}=B_M+B_2(\Phi-\Phi_M)^2 \qquad (2)$$

Where the constants B_M, B_2, and Φ_M depend on fuel type and are given in table 1 The temperature and pressure exponents, γ and β, are functions of the equivalence ratio, expressed as

$$\gamma = 2.18 - 0.8(\Phi - 1)$$

$$\beta = -0.16 + 0.22(\Phi - 1).$$

The term d_{il} is the mass fraction of diluents present in the air-fuel mixture. Recirculation of exhaust or flue gases is a common technique used to control oxides of nitrogen in many combustion systems and in internal combustion engines, residual combustion products mix with the incoming charge under most operating conditions.

Table 1 values for B_M, B_2, and Φ_M

Fuel	Φ_M	B_M cm/s	B_2 cm/s
Methanol	1.11	36.92	-140.51
Propane	1.08	34.22	-138.65
Isooctane	1.13	26.32	-84.72
RMFD-303	1.13	27.58	-78.34

Example

Compare the flame speed of gasoline-air mixture with Φ = 0.8 for the following three cases:

1. At reference conditions of *T* = 298 K and *P* = 1 atom.

2. At conditions typical of a spark-ignition engine operating at wide-open throttle: *T* = 685 K and *P*= 13.38 atom.

3. Same as condition 2 above, but with 15 percent (by mass) exhaust-gas recirculation .

Solution We will employ the correlation of Metghalchi and Keck, equation (1),. The flame speed at 298 K and 1 atom is given by:

$$S_{L,\mathrm{ref}} = B_M + B_2(\Phi - \Phi_M)^2$$

where, from Table 8.3,

$$B_M = 27.58 \text{ cm/s},$$
$$B_2 = -78.38 \text{ cm/s},$$
$$\phi_M = 1.13.$$

Thus,

$$S_{L,\mathrm{ref}} = 27.58 - 78.34(0.8 - 1.13)^2,$$

$$\boxed{S_{L,\mathrm{ref}} = 19.05 \text{ cm/s}}$$

To find the flame speed at temperatures and pressures other than the reference state, we employ equation below

$$S_L(T_u, P) = S_{L,\text{ref}}\left(\frac{T_u}{T_{u,\text{ref}}}\right)^{\gamma}\left(\frac{P}{P_{\text{ref}}}\right)^{\beta}$$

where

$$\gamma = 2.18 - 0.8(\Phi - 1)$$
$$= 2.34$$
$$\beta = -0.16 + 0.22(\Phi - 1)$$
$$= -0.204.$$

Thus,

$$S_L(685\text{ K}, 18.38\text{ atm}) = 19.05\left(\frac{685}{298}\right)^{2.34}\left(\frac{18.38}{1}\right)^{-0.204}$$

= 19.05(7.012)(0.552)

SL = 73.8 cm/s

With dilution by exhaust gas recirculation the flame speed above is reduced by the factor $(1\text{-}2.1Y_{dil})$

SL(685K,18.38atm) =73.8 (1-2.1(0.15))

SL=50.6 cm/s